

Lawrence Livermore National Laboratory

Criticality Alarm System Testing at LLNL, UC-Davis, and CEA-Valduc



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Background

- In September, 2010, a dozen detectors checked for testing at the SILENE reactor in Valduc, France,
- 4 Detectors used in 3 different pulses, bare (10/11/10), lead reflected (10/13/10), and polyethylene reflected (10/19/10) SILENE reactor,
- Neutron detector LED alarm indicator checked to verify that the detector alarms during criticality accident situation,
- Integrated counts in LCD were recorded to determine the relative importance of thermal fluence at 4 different detector locations,
- Each detector connected to a data acquisition system that was set up and controlled by a laptop computer system,
- Cs-137 gamma ray exposure testing performed (1/19/11),
- Experimental results for foils will be validated by COG modeling as part of the ICSBEP project.



CAS Detectors

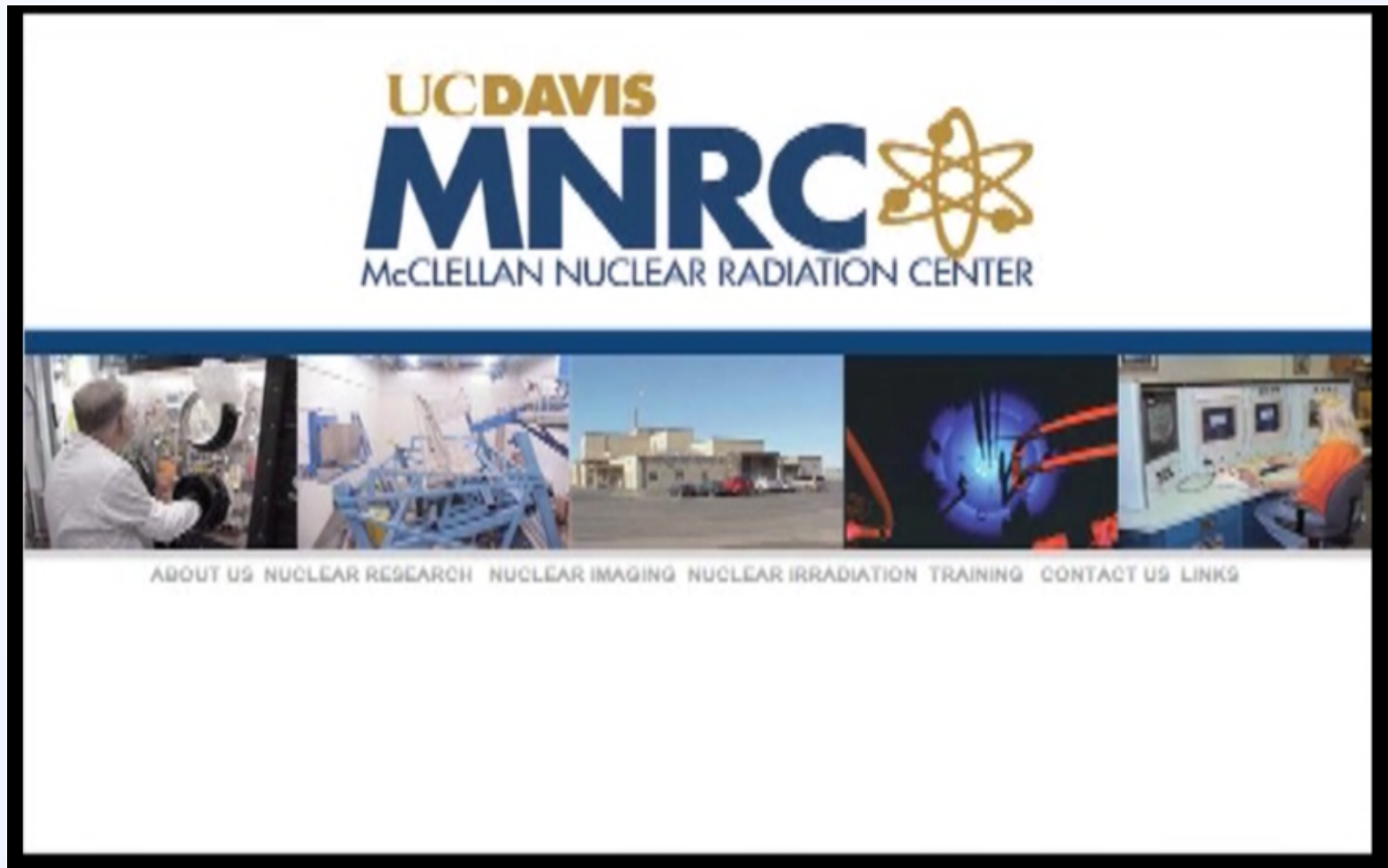
- Sensitive to thermal neutrons,
- Thermal flux measured using gold foils with/without cadmium jacket,
- Set to alarm at 16 counts per second,
- Minimum required thermal flux to alarm: 500 n/cm²-sec,
- Maximum survivable neutron fluence: 6×10^{12} n/cm²,
- Maximum survivable dose rate: 3×10^8 rads(Si)/sec.



CAS Detectors



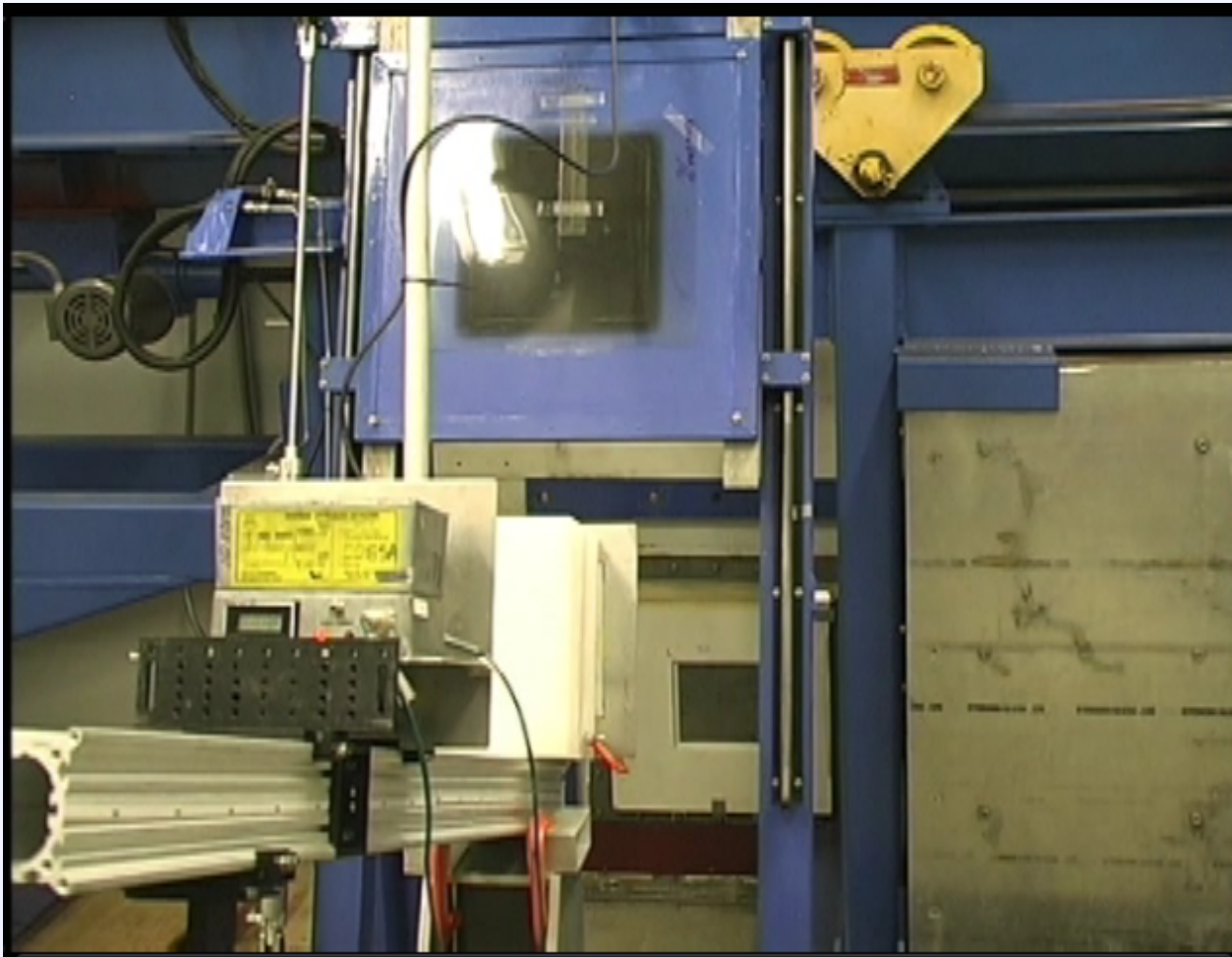
Detectors Calibrated at a TRIGA Reactor



Detector on Rail in TRIGA Test Bay



Detector under Test (Shutters open)



Detector Neutron Response / Sensitivity

- Desired exposure $\sim 500 \text{ n/cm}^2\text{-sec}$
- Reactor operated at low power – 140KW
- 3 -1 mm. BorAl plates and 8" of polyethylene

Detector No.	Detector ID	Detector Count rate Avg. of 3 1 minute tests (cpm)	Thermal Neutron Flux ($\text{n/cm}^2\text{-sec}$)	Detector Normalization Factor Count Rate / Thermal Flux
D1	ND-0028	13,261	551	24.07
D2	ND-0242	6,779	585	11.59
D3	ND-0632	4,226	549	7.70
D4	ND-0450	8,177	569	14.37



SILENE Test Cell



View of interior of SILENE test Cell

Vertical stainless steel reactor vessel

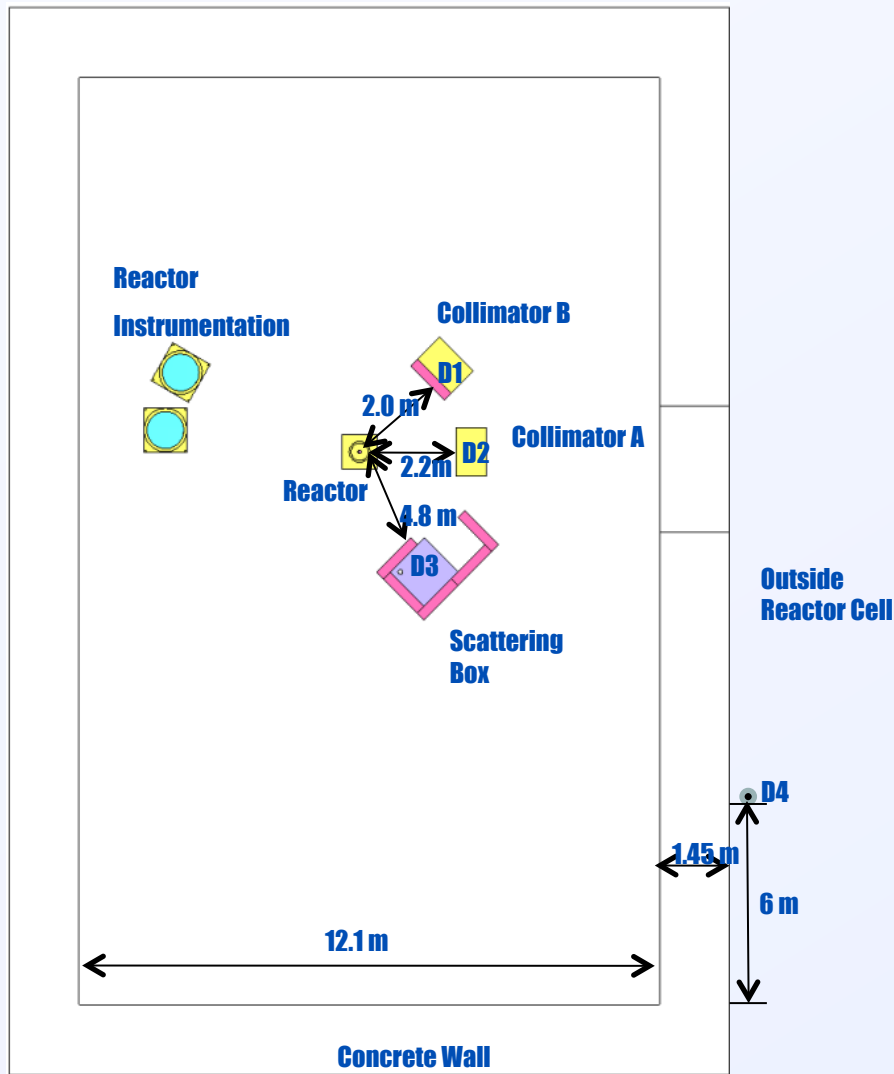
Vessel contains uranyl nitrate solution

Cylinder approx. 36 cm. dia x 42 cm. tall

Control rod operates in 4 cm. central annulus

Lead shielding arrays on trolleys near core

Detector Placement at SILENE



Detector No.	Detector ID	Cell Location
D1	ND-0028	Collimator B
D2	ND-0242	Collimator A
D3	ND-0632	Scattering Box
D4	ND-0450	Outside Reactor Cell

LED Alarm Indicator

Detector No.	Detector ID	Cell Location	Alarm LED Lit ?		
			Pulse #1 (1.9E17)	Pulse #2 (2.1E17)	Pulse #3 (1.9E17)
D1	ND-0028	Collimator B	Yes	Yes	Yes
D2	ND-0242	Collimator A	Yes	Yes	Yes
D3	ND-0632	Scattering Box	Yes	No*	No*
D4	ND-0450	Outside Reactor Cell	Yes	Yes	Yes

* Suspect weak external batteries for alarm LED



Integrated LCD Counts (Normalized)

Detector No.	Detector ID	Cell Location	Pulse #1	Pulse #2	Pulse #3
D1	ND-0028	Collimator B	22,058	22,866	19,382
D2	ND-0242	Collimator A	78,308	63,656	69,617
D3	ND-0632	Scattering Box	125,664	115,973	67,114
D4	ND-0450	Outside Reactor Cell	-*	721	115

* Not logged by record-keeper



Normalized Laptop Logged Counts

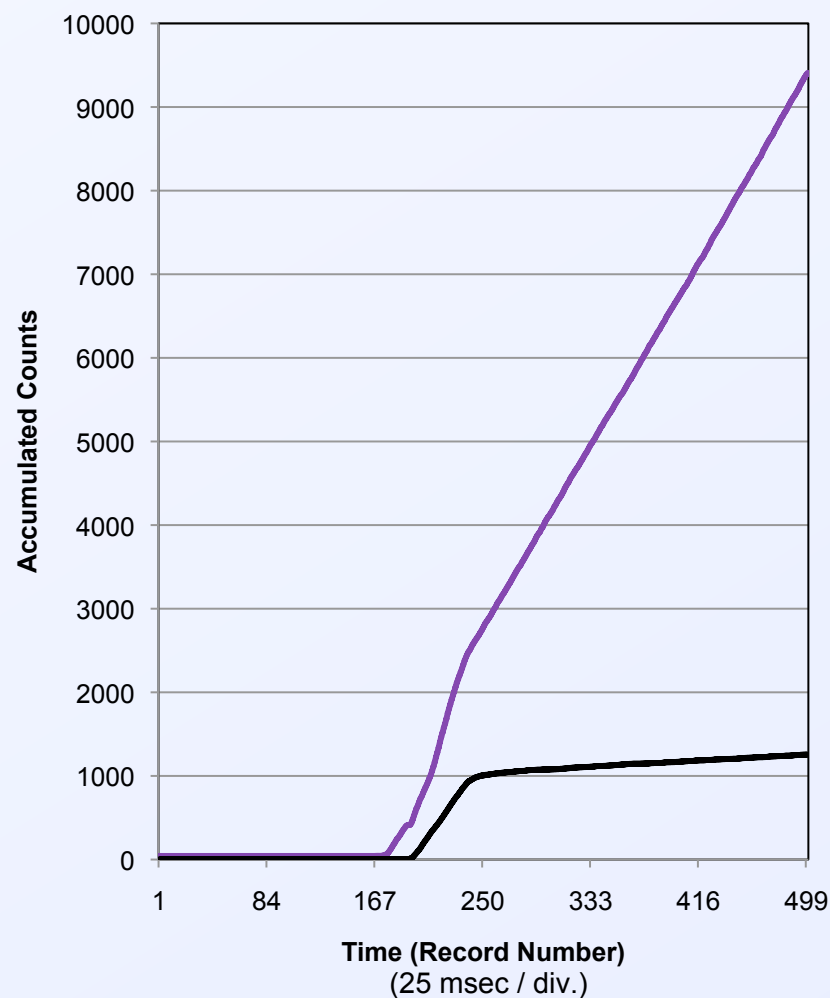
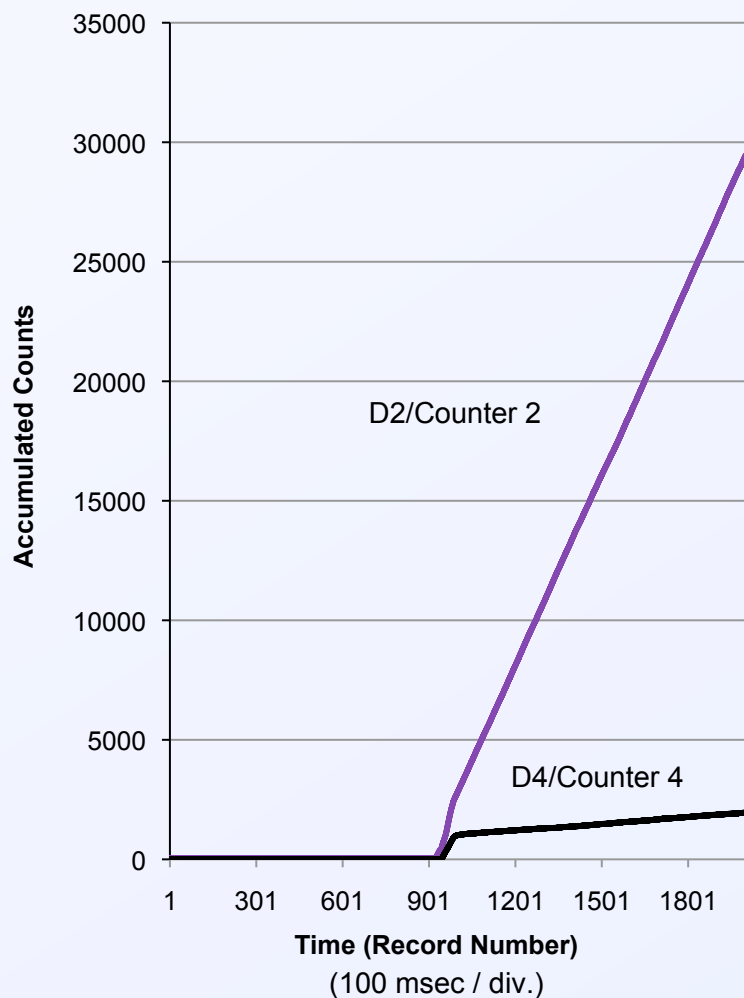
Detector No.	Detector ID	Cell Location	Pulse #1 (10/11/10)	Pulse #2 (10/13/10)	Pulse #3 (10/19/10)
D1	ND-0028	Collimator B	35,206	- (1)	- (2)
D2	ND-0242	Collimator A	71,973	153,594	- (2)
D3	ND-0632	Scattering Box	83,446	- (1)	- (2)
D4	ND-0450	Outside Reactor Cell	709	748	- (2)

(1) Detectors functioned locally, data transmission problem

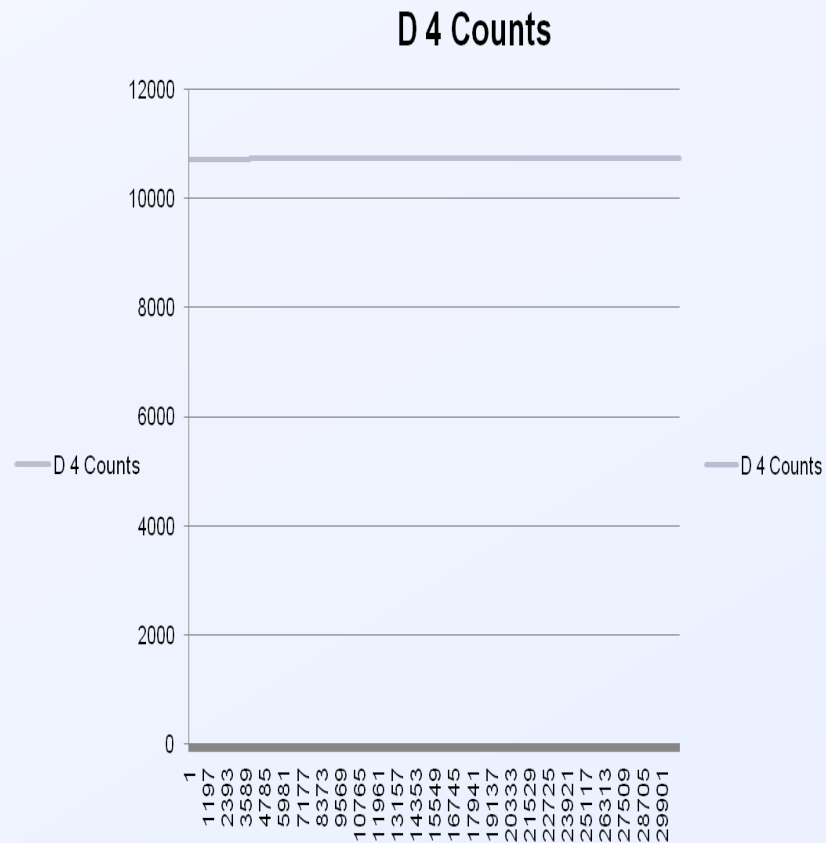
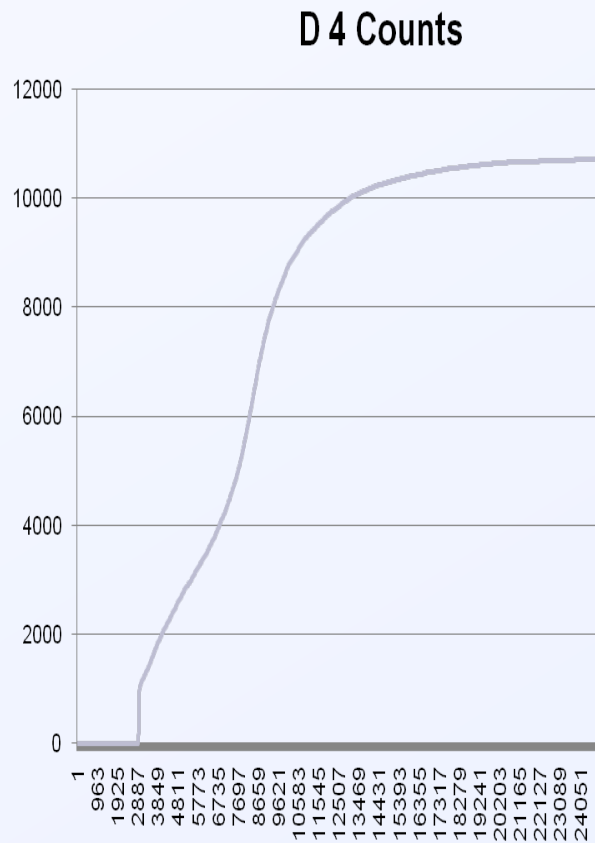
(2) LLNL staff not present



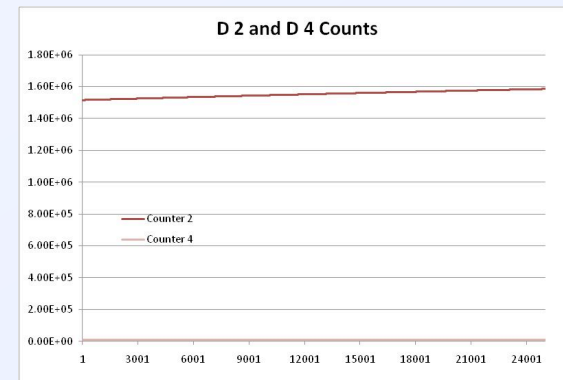
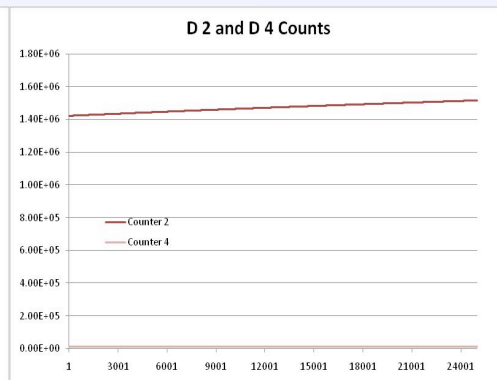
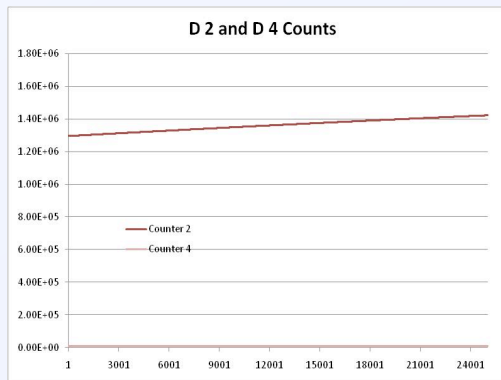
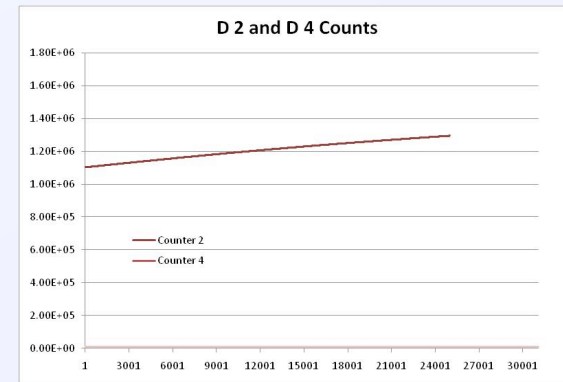
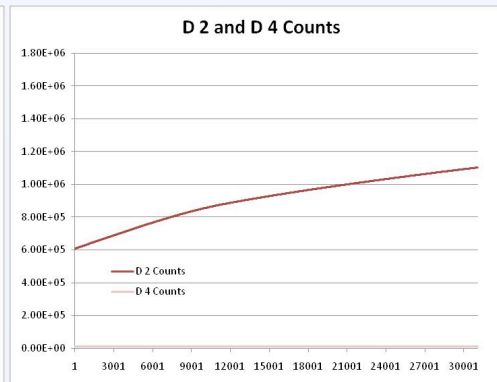
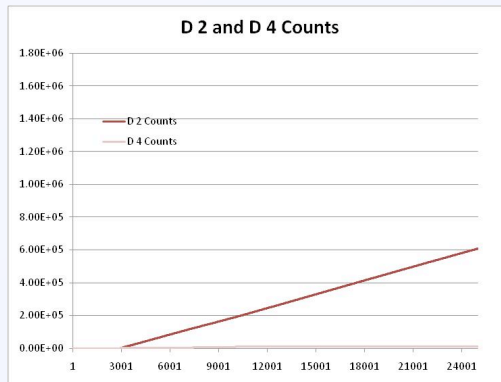
Integrated Counts vs. Time for Pulse #2



D4 Integrated Counts vs. Time for Pulse #2



Integrated Counts vs. Time for Pulse #2



Gamma Ray Sensitivity

Cs-137 Shots on January 19, 2011, LLNL Gamma Ray Irradiation Facility

Detector ID	Number of Alarms (per minute)				
	100 mR/hr	650 mR/hr	1 R/hr	1 R/hr (Detector Reversed)	1R/hr (No LiF Disk)
NCD-0997	0 (0 counts)	2	5	4	4
NCD-0596	0 (30 counts)	17	47	47	44
NCD-0450	0 (12 counts)	33	93	85	83
NCD-0633	0 (19 counts)	39	101	86	90



Summary

- Rocky Flats neutron detectors will function as intended in an actual criticality situation,
- Thermal neutron fluence seems to be highest in Scattering Box for Pulses #1 and #2, Collimator A for Pulse #3, however, Cs-137 shots on 1/19/11 indicate that the neutron detectors are very sensitive to gamma ray dose rate above 100 mR/hr,
- Detectors will be inspected and tested for any changes in electrical parameters after shipment back to LLNL,
- Experimental results for foils will be validated using COG for ICSBEP project.

